Increasing Student Confidence and Understanding with the Implementation of Inquiry-Based Modeling in a High School Chemistry Classroom

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Background

With the release of the Next Generation Science Standards (NGSS), modeling was an important concept in the new standards being released (NGSS Lead States, 2013). Also, with the release of revised Advanced Placement (AP) Chemistry standards in 2014, there was a shift in focus from recall to enduring conceptual understanding (The College Board, 2014). Chemistry requires students to understand concepts on atomic, subatomic, and molecular levels. This means that students need to grasp abstract and microscopic ideas, which can be difficult to visualize and transfer into a real-life comprehension. Physical and spatial modeling was a critical factor in improving understanding (Yakmaci-Guzel & Adadan, 2012).

Because of this shift in education, I chose to implement student-based modeling in my AP Chemistry class. I engaged my students in creating physical models using a variety of mediums and monitored their attitudes and understanding throughout the process.

Research Questions

Table 1
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4
Primary Question: How will the implementation of inquiry-based modeling impact students in the chemistry classroom?	Modeling in Chemistry Survey	Interview Questions	Teacher's Journal	Both Performance Assessments
Sub-Question 1: What is the effect of inquiry-based modeling on student achievement in chemistry?	Thermochemistry Pre- and Post-Test	Spontaneity, Entropy, and Free Energy Pre- and Post-Test	Performance Assessment: Ice Cube Melting Model	Performance Assessment: Enthalpy, Entropy, and Temperature
Sub-Question 2: What is the effect of inquiry-based modeling on student attitudes about chemistry?	Modeling in Chemistry Survey	Interview Questions	Teacher's Formal and Informal Observations	Teacher's Journal

Methodology

The treatment of this study included intentional use of models for students throughout two units in the AP Chemistry curriculum. The student population consisted of two classes, totaling 53 students, of 11th and 12th grade AP Chemistry students at Artesia High School in Lakewood, CA. For every topic covered within the two units, modeling was prompted by the teacher and completed by the students in the classroom. This treatment occurred from February 2017 to April 2017. These models were based off of concepts in the NGSS and College Board's Course and Exam Description and were inquiry-based models.
Students took content-based pre-tests and post-tests for both units of treatment. These results were compared for normalized gains. The post-test data was also collected between the 2015-2016 school year and 2016-2017 school year, and was analyzed and reported in box and whisker plots.
A Likert-style survey, Modeling in Chemistry Survey, was administered pre-treatment and post-treatment to monitor student attitudes during the modeling treatment.

Results

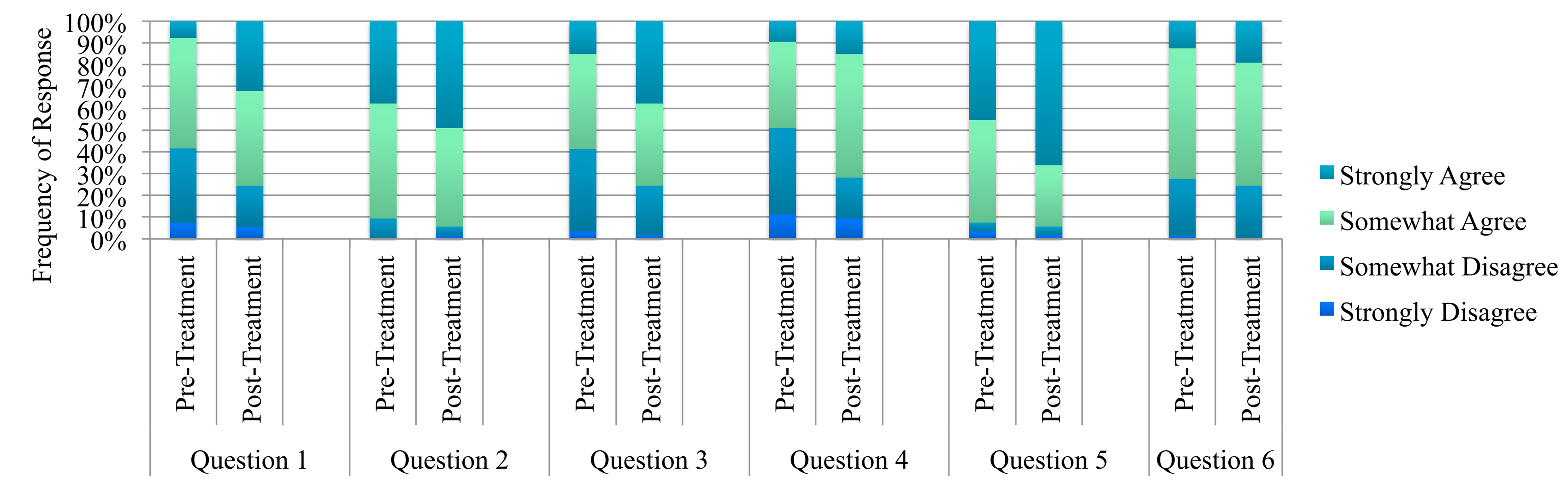

Figure 1. Modeling in Chemistry Survey results, (*N*=53).
Note. Question 1: I regularly create a mental model of the concepts I learn in chemistry. Question 2: I better understand chemistry problems after I create a model of the concept. Question 3: I enjoy making models of chemical concepts. Question 4: I am confident in my ability to create models in chemistry. Question 5: Making models helps me better understand chemistry. Question 6: I am good at chemistry.

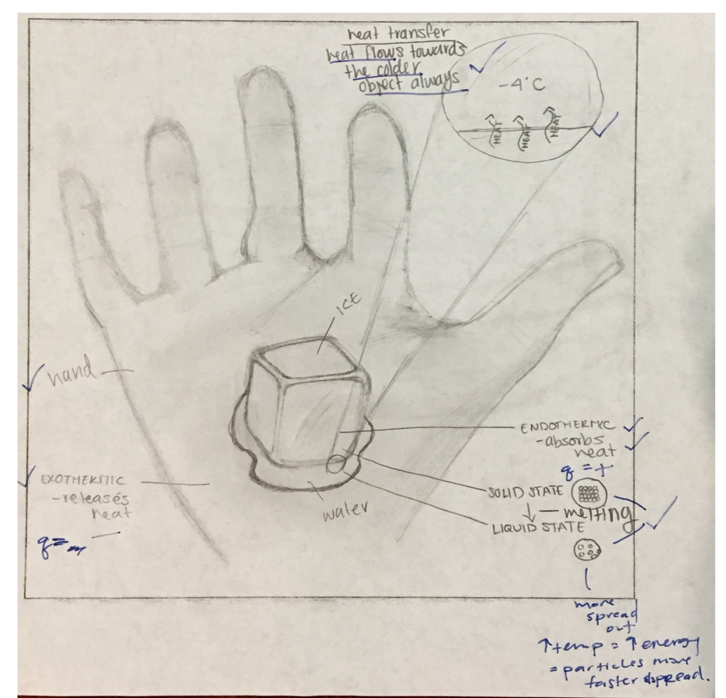

Figure 2. Ice Cube Melting Student Model.
Note. The pencil writing was done by a student. The blue writing was done by the teacher.

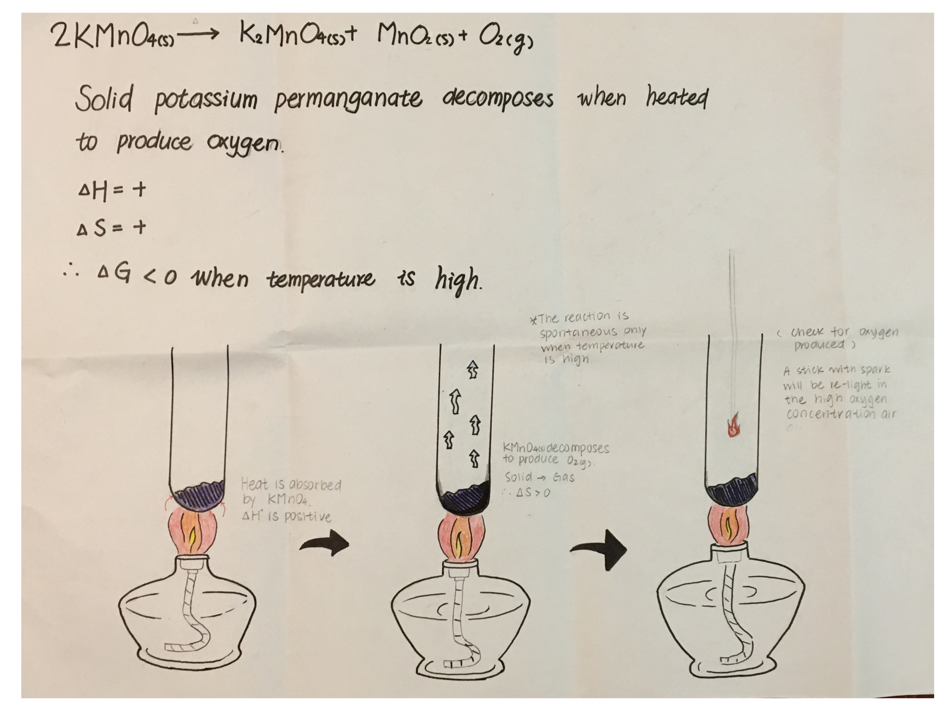

Figure 3. Student Model of the Relationship Between Enthalpy, Entropy, Temperature, and Free Energy.

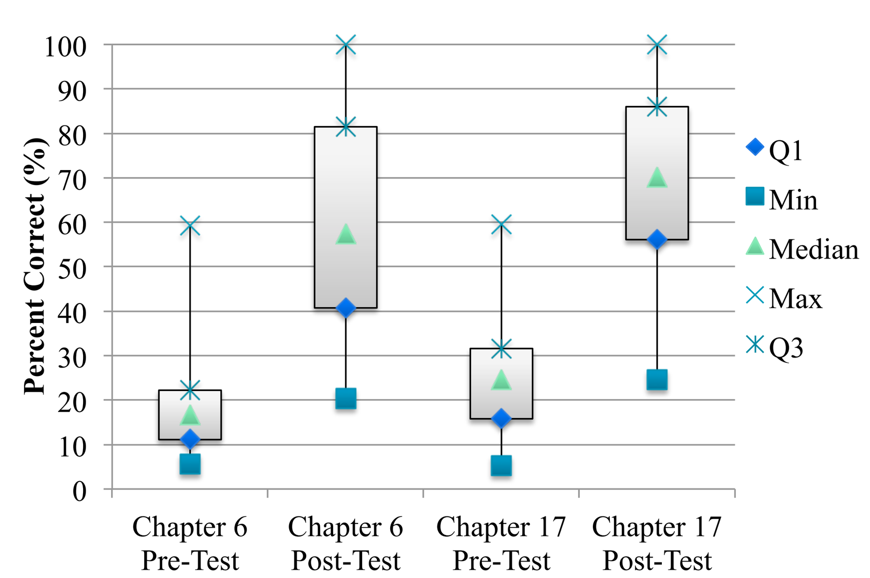

Figure 4. Score distributions of test percentages of Chapter 6 and 17 pre-test and post-test, (*N*=53).

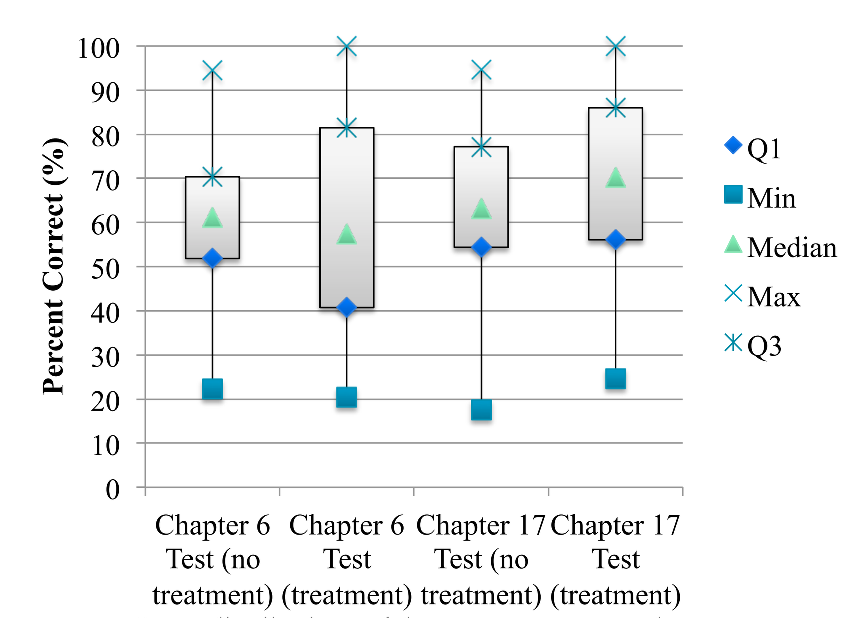

Figure 5. Score distributions of the non-treatment student groups compared to the treatment groups of students, (*N*=76) (*N*=53).

References

College Board. (2014). AP Chemistry: exam and course description. Retrieved from www.collegeboard.org
NGSS Lead States. (2013). Next Generation science standards: for states, by states. Retrieved from http://www.nextgenscience.org/
Yakmaci-Guzel, B., & Adadan, E. (2012). Use of multiple representations in developing preservice chemistry teachers' understanding of the structure of matter. *International Journal of Environmental and Science Education, 8*(1), 109-130.

Results (cont.)

The results of the Modeling in Chemistry Survey indicated that students responded positively towards modeling in the chemistry classroom and that they used modeling more after the treatment than before. One student stated, "I wish we had included more models in the beginning of the year because it would have been more beneficial." When asked if students better understand chemistry concepts when creating models, 37.7% of students responded *strongly agree* pre-treatment while 49% of students had the same response post-treatment. A student stated, "Modeling affected my learning in chemistry in the sense that I am better able to conceptually understand what is going on because it is easy to do the math portion but if I cannot conceptually understand it then what is the point?" An increase from 15.1% to 37.7% of students responded *strongly agree* when asked if they enjoy making models of chemical concepts. One student stated, "I enjoy making models after learning the chemical concepts because it helps me understand what we just learned about and puts an image in my head of what is actually happening in chemistry." Students who *strongly agree* that making models helped them better understand chemistry increased from 45.3% of students pre-treatment to 66% post-treatment. One student stated, "Before I would just be memorizing and then regurgitating. Modeling forced me to make the concept for myself rather than following a set concept that would not contribute to my personal learning of the subject." Post-treatment, 1.9% of students responded *strongly disagree* when asked if making models helps them better understand chemistry. One student stated, "I need people to explain to me what is going on in order for me to understand a concept, so trying to figure out what is happening on my own confuses me more." When comparing the pre-test and post-test scores, the average student score on both the Chapter 6 Test and the Chapter 17 Test increased by 43.4% for both tests (Figure 4). The results of the Chapter 6 and Chapter 17 post-tests from the treatment group of students (*N*=53) was compared to the scores from my students the year prior, who did not receive any treatment (*N*=76). The treatment group's average score was 2.9% higher for the treatment group compared to the non-treatment group on the Chapter 6 Test. For the Chapter 17 Test, the treatment group had an average score of 3.7% higher than the non-treatment group (Figure 5). One student stated, "At first I did not have a conceptual understanding which prohibited me from creating a proper model and understanding the subject. However, as time progressed and more model making assignments and projects were instituted I was able to understand the concept and properly model what was going on."

Conclusions

This study provided evidence that incorporating modeling into my classroom curriculum positively affected student achievement and attitudes in chemistry. According to the data, students were impacted by the implementation of modeling in the chemistry classroom. Student achievement in chemistry deviated only slightly from the previous year, which received no treatment, during the first chapter of treatment. It is evident, however, that there is a larger increase in achievement during the second chapter. When implementing modeling, I noticed that my students were not familiar with creating visuals and hadn't been challenged to contemplate conceptual concepts prior to the treatment. Because of this, I think the students took more time than I had expected to get comfortable with thinking conceptually, making mental models, and creating visual representations of their understandings of chemistry concepts. By the time Chapter 17 was started, which was the second chapter in the treatment plan, students were beginning to be more confortable with modeling and I noticed that students began making better models. As the data shows, the students have a slightly larger normalized gain in the second chapter compared to the first of the treatment. When comparing the scores on the same exams of my students from the previous year, who did not receive treatment, the group of students who received treatment showed higher scores comparatively as the treatment progressed. The achievement of my students who received treatment increased as they had more exposure and practice with creating their own models.

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